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Aggregate Resources Inventory of the City of Guelph and Guelph Township
Wellington County
Southern Ontario

By Staff of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

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Aggregate Resources Inventory of the City of Guelph and Guelph Township Wellington County

by Staff[1] of the Cambridge District Office, Ontario Ministry of Natural Resources, and Staff[1] of the Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Affairs and Mines

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Abstract

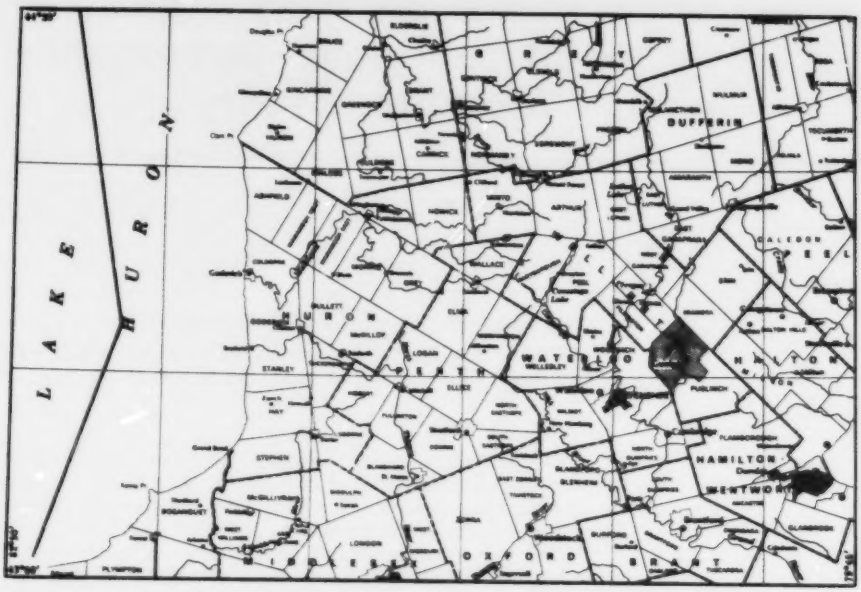


Figure 1. *Key Map Showing the Location of the City of Guelph and Guelph Township, Scale 1:1 800 000.*

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in the City of Guelph and the Township of Guelph. The report is part of the Aggregate Resources Inventory Program for townships designated under the Pits and Quarries Control Act.

In the report area, four areas containing significant amounts of sand and gravel have been selected for possible resource protection. Selected Sand and Gravel Resource Areas occupy 3400 acres (1380 ha), exclusive of licenced properties. An estimated 2300 acres (930 ha) are currently available for extraction, containing possible resources of 94 million tons (85 million tonnes). The parts of the selected areas which are available for extraction represent about 9 percent of the total area occupied by sand and gravel deposits in the municipalities and 10 percent of the total resource tonnage.

Selected Sand and Gravel Resource Area 1 is a large terraced outwash deposit near the city's eastern boundary with the township. Area 1 contains an estimated 11 million tons (10 million tonnes) of sand and gravel which is acceptable for high-specification road base and surfacing aggregate.

Selected Sand and Gravel Resource Area 2 is a large outwash deposit of variable thickness and stone content near Marden. The Area contains a possible resource of 38 million tons (34 million tonnes) but the variability of the deposit may present operational difficulties for commercial development.

Selected Sand and Gravel Resource Area 3 is also a terraced outwash deposit which is part of the former spillway system extending along the Speed River. Area 3 contains estimated resources of 26 million tons (24 million tonnes) and supports a large commercial operation on its lower terrace.

Selected Sand and Gravel Resource Area 4 is an extension of an outwash deposit selected for resource protection in Puslinch Township, and contains possible resources of 19 million tons (17 million tonnes).

The City of Guelph and Guelph Township have possible sand and gravel resources which could meet local requirements for a number of years. The selected areas contain significant resources and as much as possible of the existing material should be protected for future development.

The municipalities in the report area are underlain by bedrock of the Amabel Formation and Guelph Formation. Three areas in the Guelph Formation, a rock unit best suited for the production of lime and metallurgical stone, have been selected

for possible resource protection. The selected areas cover 1390 acres (560 ha) and contain possible resources of 280 million tons (255 million tonnes).

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, test pitting, soil probing, hand augering and geophysical techniques are used to assess subsurface materials. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100- pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests along with petrographic analyses are performed.

Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. In areas of limited subsurface exposure, test holes are drilled and geophysical surveys using hammer seismic equipment are undertaken. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Map 1.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data. The information was then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography

maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

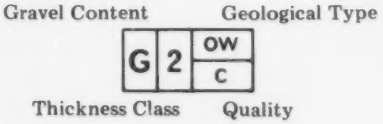
Map 1 is derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

Test hole locations are shown on Map 1 by a solid drill hole symbol. Geophysics lines are shown on the map by a line symbol.

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light shading on Map 2. Such deposits are believed

to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single, land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the litholgy of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the

basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three levels of shading. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource ares. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. One additional symbol appears on the map: an open dot indicates the location of a selected drill hole which penetrates bedrock. The overburden thickness is shown in feet beside the open dot.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting

criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approch. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III — Assessment of Aggregate Resources in the City of Guelph and Guelph Township

LOCATION AND POPULATION

The City of Guelph has an area of 16,978 acres (6871 ha); Guelph Township occupies 29,170 acres (11 805 ha) around the city's perimeter. Both municipalities are located in the southwestern corner of Wellington County, and are served by well developed transportation routes including railway lines, paved provincial highways and municipal roads. These municipalities are shown on the Guelph (40 P/9) and Cambridge (40 P/8) map sheets of the National Topographic System at a scale of 1:50 000.

Guelph is a regional trade and retail centre for Wellington County with a significant, local industrial economic base. As of 1982, the City had a population of 76 658, an increase of approximately 25 percent since 1972 (Ontario Ministry of Municipal Affairs and Housing 1983; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). In contrast, Guelph Township (Pop. 2932) has a largely rural character comprised of active farm operations and limited rural-estate residential development.

Demand for aggregate can be expected to keep pace with current population trends. As well, the increasing popularity of rural-residential development in the township poses a severe constraint on extractive land use, often sterilizing potential mineral aggregate resource areas.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Most of the report area lies within the Guelph Drumlin Field, a physiographic unit described by Chapman and Putnam (1984, p. 138) as being composed of "groups of drumlins fringed by gravel terraces and separated by swampy valleys in which flow sluggish tributaries of the Grand River." The City of Guelph is built around the largest of these tributaries, the Speed River. Bedrock forms the river bed as it traverses a broad terraced valley from northeast to southwest.

The form and distribution of surficial material, including the sand and gravel deposits shown on Map 1, are the result of glacial activity that took place in the Late Wisconsinan Substage of the Pleistocene Epoch. This period of time, which lasted from approximately 23 000 to 10 000 years before present, was marked by the repeated advance and melting of extensive, continental ice sheets.

At the time of maximum glacial extent, part of central southern Ontario, including the Guelph area, was covered by a submass of the ice sheet known as the Lake Ontario lobe (Karrow 1968). The margin of the Ontario lobe advanced to the northwest over the study area and deposited a moderately stony, sandy silt till (Port Stanley Till, Karrow 1974). The streamlined mounds of till known as drumlins making up the Guelph Drumlin Field were formed at this time. The till has little value as an aggregate source because of its high silt content, but is well suited for cultivation.

Meltwaters flowing at the base and at the margin of the ice left stratified sands and gravels referred to as ice-contact deposits (kames and eskers). Kame deposits are only associated with the Paris Moraine complex in the southern part of the report area but eskers, which are sinuous ridges of predominantly coarse aggregate, are well developed throughout. Trending in a southeast to northwest direction, the Eramosa, Ariss and Guelph Eskers were an important early source of coarse aggregate, but are now largely depleted or inaccessible.

Ice-marginal spillways containing meltwaters seeking an outlet to the south and west also deposited stratified sands and gravels. As the Ontario lobe halted at the Paris Moraine (south of the report area in Puslinch Township), a major spillway or valley outwash system developed along the present Speed River valley through Guelph and deposited variable thicknesses of uniform outwash materials, in places burying drumlins. These terraced deposits form the best quality aggregate sources for the Guelph area and contain material suitable for a variety of crushed products.

Shallow sandy or silty materials occur infrequently in depressions or on top of spillway materials as a result of temporary pondings during deglaciation.

EXTRACTIVE ACTIVITY

The City of Guelph and Guelph Township were designated under the Pits and Quarries Control Act on May 9, 1972. At the time of report preparation, five operations have a total licenced area of approximately 427.8 acres (173.1 ha) (see Tables 2 and 5). Two of these operations are licenced to quarry stone (Table 5).

The study area has supported moderate extractive activity in the past and with the growing urban community many of these sites are now depleted. The majority of the sources (23 pits shown on Map 1 and Map 2) have been rated low or low to moderate by the Ontario Ministry of Transportation and Communications (M.T.C.) because of a general scarcity of crushable size material (Deike 1981). Those rated moderate, as noted elsewhere, should contain sufficient crushable material for the production of Granular Base Course (G.B.C.) A road base material as well as for G.B.C. B sub-base aggregates. However, because of deposit variability, the production of hot-mix gravel on a long term commercial basis might prove impractical.

Several of the once productive but now depleted pits are of assistance in describing the quality and suitability of adjacent resource areas. Guelph Sand and Gravel Company had a large operation at Lot 2, Concession I, Division E and Lot 21, Division A, Guelph Township (now in the City of Guelph). Thickness of the deposit was estimated at 17 feet (5 m), some of this below the water table. Stone content was reported as 25 percent. An asphalt plant was associated with the operation and ready mix and concrete block plants were located nearby (Hewitt and Karrow 1963).

Three operations originally licenced in the Watson Road area (pit nos. 15, 16 and 17) were a major source of high quality aggregate for Guelph. Hewitt

and Cowan (1969) reported that a maximum 20-foot (6 m) face exposed stratified sand (60 percent) and medium gravel (40 percent). These properties were expropriated in 1973 to allow for the construction of the Guelph Dam and Reservoir and extraction continued until about 1975 when the area was flooded.

Since the designation of the report area under the Pits and Quarries Control Act, the Cambridge District Office of the Ontario Ministry of Natural Resources has recorded the total annual production of sand and gravel and crushed stone from all licenced sources and wayside pits. The average annual production between 1977 and 1981 in Guelph Township and the City of Guelph was 346,000 tons (313 900 tonnes). Wayside pits, opened to meet the requirements of local road authority projects, had an average annual production over the same time period of 184,300 tons (167 200 tonnes). A large portion of this has been derived from Lots 15 and 16, Concession 3, Division "D", Guelph Township (pit no. 9) which allowed the development of a township recreational park including a 6-acre (2 ha) lake.

SELECTED SAND AND GRAVEL RESOURCE AREAS

The sand and gravel deposits selected for possible resource protection in the City of Guelph and Guelph Township are shown on Map 2. Most of the resources still available for possible resource utilization lie within Guelph Township. The selected areas include outwash deposits along the Speed River and near Marden which represent the best quality sources in the report area. Special attention has been paid to select relatively large intact areas where existing uses do not appear to limit the future availability of the resource. Coarse aggregate quality in the selected areas is primarily of high calibre and cherty or shaly material is generally absent or, in some areas, present only in very small percentages. Deposit variability and unpredictability can be a major problem. Silt- and clay-rich seams or pockets (which result in increased extraction costs) must be avoided. As well, blending of the variably graded sand fractions may be required in order to meet hot-mix sand specifications (Deike 1981).

In addition, three outwash deposits and one esker deposit have been selected as resource areas at the secondary level. Although these areas are not the 'best' deposits in the report area, they contain aggregate that may be useful locally. Consequently, they should be considered as an important part of the resource base.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Resource Area 1 is located on the east side of the City of Guelph and in Guelph Township and is part of the Speed River spillway system. The double terraced deposit occupies a total unlicenced area of 425 acres (172 ha) with estimated depths of 18 feet (6 m) and 12 feet (4 m).

This well stratified deposit contains one licenced property (pit no. 1) and one abandoned site (pit no. 20). A large quantity of crushable gravel (stone content is 50 percent or higher including oversize material) is available above the water table. The M.T.C. has rated sources within this deposit as moderate to high (Deike 1981). Open faces show two distinct granular layers of 2 to 4.5 feet (0.6 to 1.4 m) and 2 to 9 feet (0.6 to 3 m) separated by a 0.5- to 2-foot (0.2 to 0.6 m) bed of medium to fine sand. Material derived from this deposit is acceptable for a wide range of products including Hot-Laid (H.L.) No. 4 asphaltic mixes and road sub-base (Granular Base Course A, B and C). Sand gradings may vary and require blending for hot-laid aggregates.

Existing residential uses, the Guelph airport and industrial land recently serviced by the City of Guelph, severely limit the future availability of this resource area. After accounting for these cultural constraints and previously extracted areas, 270 acres (110 ha) remain available for possible resource extraction. Assuming an average thickness of 18 feet (6 m) in the upper terrace and 12 feet (4 m) in the lower terrace, the presently available resources are estimated to be 11 million tons (10 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

At present, there are no licenced operations in this selected area, but in the past the outwash deposit has supported two operations (pit no. 8 - Marden Redi-Mix and pit no. 9 - Guelph Township Park) which have been rated moderate to high by the M.T.C. The deposit is variable and irregular, consisting of outwash deposited in low areas between drumlins. Testing by McLellan (1975) for the development of a recreational park showed an unpredictable content of crushable materials (pit no. 9). Stone content as low as 4 to 20 percent has been reported (Deike 1981). Although the water table is close to the surface, deposit thicknesses of up to 25 feet (8 m) have been found. Testing by the M.T.C. has shown that, with selection, granular materials are acceptable for a wide range of products including H.L. 4 asphaltic mixes and road sub-base (Granular Base Course A, B and C). However, the variability of this deposit may present operational problems for commercial development.

Existing rural-residential uses along major access routes partially limit the availability of this resource area. After accounting for cultural constraints and previously extracted areas, the remaining area of approximately 1020 acres (415 ha) contains a possible resource of 38 million tons (34 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Resource Area 3 consists of a terraced outwash deposit, again part of the former spillway or valley outwash system along the Speed River. It has also been selected as a primary resource area in Puslinch Township. The lower terrace has a thickness of 30 feet (9 m) or more of well stratified sand and gravel with a stone content of 60 percent. Although parts of the deposit can grade dirty for some uses, road sub-base products such as G.B.C. A, B and C can be produced (Deike 1981). The gravels are also suitable for 16 mm crushed stone, hot-laid asphalt and concrete uses, provided that suitable processing is carried out. Most of the deposit area is licenced to Standard Aggregates (pit no. 4) as both a pit and a

quarry. This large commercial operation has washing and asphalt facilities to supply a wide range of products for the Guelph and Cambridge markets (Trauffer 1976).

The larger upper terrace is notably thinner (about 15 feet (5 m)) and sandier (stone content 20 percent). Existing pits have only supplied road sub-base materials in the past and detailed test information is not available.

Industrial development along King's Highway 24 limits the availability of this resource area. After subtracting cultural setbacks, 520 acres (210 ha) outside of the licenced properties are available for extraction, and contain estimated resources of 26 million tons (24 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 4

Selected Resource Area 4 is part of an extensive outwash deposit which lies immediately north and west of the Paris Moraine (and has been selected as a primary resource in Puslinch Township). Extractive activities have not been extensive in the City of Guelph part of the deposit. But on the basis of detailed testing conducted in the outwash deposit located in Puslinch Township (Dominion Soil Investigation Inc. 1979), aggregate is coarser near the surface and becomes finer with depth. Average thickness is 15 feet (5 m) but underlying the coarse aggregate is an additional 23 feet (7 m) (average) of fine material marginally suitable for granular use. The upper portion appears suitable for G.B.C. B and C with some portions suitable for crushing into G.B.C. A. With processing, some parts of the deposit would be suitable for concrete and asphalt sand.

Resource Area 4 occupies 720 acres (290 ha), but after allowing for cultural setbacks such as a major highway corridor and an industrial subdivision, only 495 acres (200 ha) are estimated presently available for extraction. Assuming an average thickness of usable material of 15 feet (5 m), the presently available resources total approximately 19 million tons (17 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Three outwash deposits and one small esker deposit are shown by a light tone on Map 2. The deposits have been selected as secondary resource areas because their topography, size or quality may limit their commercial value. Although these deposits are not the 'best' resources they should be considered an important component of the municipalities' aggregate supply.

One of the outwash deposits selected at a secondary level adjoins Selected Resource Area 1. Testing by the M.T.C. and water well log data suggest that this area is less than 10 feet (3 m) thick but has sufficient quality to yield road sub-base aggregates (Granular Base Course A, B and C) and, with blending, some hot-mix asphalt products (pit no. 19).

A second outwash deposit selected at a secondary level contains thinner portions of the deposit in Selected Resource Area 2. Granular investigations have not been reported for this area and, therefore, quality information is not available.

A third outwash deposit is an eastward extension of Selected Resource Area 4. Data from water well records and from licenced sand and gravel pits in adjacent Puslinch Township indicate that the deposit is predominantly gravel with a thickness of 20 to 55 feet (6 to 17 m). However, the aggregate in this part of the outwash deposit is believed to be poorer in quality than that in Resource Area 4.

Much of the esker gravel in the report area has already been fully exploited but a small segment of the Ariss Esker remains on the northern limits of the City of Guelph. Although not subject to detailed investigation, the deposit could be a useful source of road construction aggregate.

BEDROCK GEOLOGY

Bedrock underlying Guelph Township and the City of Guelph consists of Silurian dolostone of the Amabel Formation (Eramosa Member) and the Guelph Formation. The distribution of these units is shown on Map 3 (after Telford 1976; 1979). The bedrock surface dips gently southwest with lowest elevations found along the Speed River (Karrow et al. 1979). Drift cover is sparse along the Speed River valley, but increases to as much as 100 feet (30 m) elsewhere in the report area (Vos 1969).

The Amabel Formation, the older of the two formations, is found along the eastern half of the Speed River valley in the report area. The formation has been separated into two units in the region on the basis of persistent textural differences. Only the upper unit, the Eramosa Member, is exposed in the study area and it has been described as very thin- to medium-bedded, fine-crystalline bituminous dolostone with some sandy layers. A minimum thickness of 53 feet (16 m) is exposed to the east, at Everton (Telford 1979). Because this member is not suitable for the production of load-bearing crushed aggregate, and because of the multitude of existing land uses which preclude possible extraction in the subcrop area, no areas have been selected for possible resource protection.

The Guelph Formation overlies the Amabel Formation and subcrops in the remainder of the report area. It is a buff-coloured, fine-grained, sucrosic dolostone usually of high purity (Telford 1976; 1979). A reefy facies may also be present. The Guelph Formation is generally soft and susceptible to physical weathering processes, rendering the stone unacceptable for production of most road-building or construction aggregates (occasionally, it has been crushed for granular base course or quarried for building stone). However, it is well suited for lime production because of its high chemical purity. It is quarried at several localities along the Speed River, such as at Glenchristie and Guelph, for the manufacture of dolomitic lime used in the production of quicklime and high quality, white, hydrated lime (Hewitt 1960). Outcrops of the Guelph Formation are confined to the Speed River south of the city and here two areas have been selected for possible resource protection. Extractive development also appears feasible in an area of thin overburden north of Marden.

At the turn of the century, a number of quarries were in operation, producing road construction aggregate, building stone and lime (Parks 1912) - but at present, only two properties are licenced for quarrying in the report area. One of these which has been in operation for many years is licenced to Guelph Dolime Limited (quarry no. Q1). The other quarry (quarry no. Q2), operated by Standard Industries, is licenced both as a gravel pit and as a quarry, but active quarrying of bedrock has not yet occurred. The stone from both quarries is best suited for use in the manufacture of lime and metallurgical stone. Of the several abandoned quarries in the City of Guelph, only the quarry at the Guelph Correctional Centre remains visible (quarry no. 3).

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 is underlain by the Guelph Formation dolostone. It is located in Guelph Township south of Highways 6 and 24 and extends along the Speed River valley into Puslinch Township and connects with Selected Bedrock Resource Area 2. A few outcrops occur along a small escarpment within Resource Area 1. Elsewhere, overburden thickness is always less than 25 feet (8 m) and probably less than 15 feet (5 m).

Guelph Dolime Limited has operated a quarry at Part Lots 1-5, Concession 5G, Guelph Township and Part Lots 1 and 2, Concession 4G, City of Guelph for a number of years (Hewitt 1960). The quarry face of approximately 42 feet (13 m) represents the total thickness of the Guelph Formation at this location since dolostone of the Eramosa Member (Amabel Formation) is exposed on the floor.

The Resource Area consists of 380 acres (155 ha), of which 340 acres (140 ha) are available for extraction. Assuming an average workable thickness of 45 feet (14 m), the bedrock resources presently available for extraction are estimated to be 55 million tons (50 million tonnes).

SELECTED BEDROCK RESOURCE AREA 2

Selected Bedrock Resource Area 2, located southeast of Highway 24 in Guelph Township, consists of the Guelph Formation dolostone. It is part of the larger resource area found straddling the Speed River in Puslinch Township and the City of Cambridge reports (Ontario Geological Survey 1982; in prep.).

Part of Area 2 is licenced to Standard Aggregates for quarry purposes but at present only unconsolidated material is being excavated. This resource area lies adjacent to Domtar Chemicals Group, Lime Division, Glenchristie quarry (Lots 1, 2 and 3, Concession 4, Puslinch Township) which has been operated since the turn of the century. The quarry has produced dolomitic lime, hydrated lime and limestone.

Resource Area 2 is covered by less than 25 feet (8 m) of overburden and is well served by road and rail transportation routes. The area currently available for extraction is calculated to be 190 acres (75 ha) after allowing for cultural setbacks. Assuming a workable thickness of 60 feet (18 m), possible resources are estimated to be 41 million tons (37 million tonnes).

SELECTED BEDROCK RESOURCE AREA 3

Selected Bedrock Resource Area 3 is located near the small community of Marden. Overburden thickness is less than 25 feet (8 m) and is much less in the eastern part of the resource area. Area 3 is partially overlain by an outwash deposit which has also been selected for resource protection and therefore has a combined natural aggregate and bedrock resource potential.

The Guelph Formation dolostone is generally suitable for lime production because of its high chemical purity although detailed investigation has not been undertaken in this resource area. The area currently available for extraction is estimated to be 860 acres (350 ha) after allowing for cultural setbacks. Assuming a workable thickness of 60 feet (18 m), possible resources are estimated to be 185 million tons (167 million tonnes).

SUMMARY

The City of Guelph and Guelph Township have possible sand and gravel resources which could meet local requirements for a number of years. Four areas selected for possible resource protection contain approximately 94 million tons (85 million tonnes) of granular material and are capable of providing a variety of high quality products. Several resource areas of secondary significance have also been identified. Care should be taken to ensure the continued availability of as much of these areas as possible.

Bedrock resources have been identified in the Guelph Formation, a rock important in the manufacture of lime for the chemical industry. Two resource areas along the Speed River and a resource area near Marden containing total possible resources of 280 million tons (255 million tonnes) have been selected for possible resource protection.

Enquiries regarding the Aggregate Resources Inventory of the City of Guelph and Guelph Township should be directed to the Ontario Ministry of Natural Resources either at the Cambridge District Office, Box 2186, Cambridge, Ontario, N3C 2W1 (Tel. (519) 658-9355) or at the Central Region Office, 10670 Yonge Street, Richmond Hill, Ontario, L4C 3C9 (Tel. (416) 884-9203), or to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Affairs and Mines, Room M1B-45, MacDonald Block, Queen's Park, Toronto, M7A 1W3, (Tel. (416) 965-1663).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	G-OW	4400 (1780)	219 (199)
	G-E	330 (134)	17 (15)
	G-K	72 (29)	4 (4)
2	G-OW	13,800 (5600)	520 (470)
	G-E	65 (26)	3 (3)
	G-K	1210 (490)	45 (41)
3	G-OW	400 (162)	7 (6)
	G-E	82 (33)	1 (1)
	G-K	500 (202)	9 (8)
4	G-OW	660 (267)	8 (7)
	G-E	109 (44)	1 (1)
	G-K	250 (101)	3 (3)
	S-OW	4650 (1880)	58 (53)
		26,500 (10 700)	900 (820)

TABLE 2. SAND AND GRAVEL PITS, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	G09-121	Carolyn Stradiotto	7 Guelph Twp.	2C	55.0 (22.3)	20 (6)	40
2	G09-049	J. Thourne	19 Guelph Twp.	1B	41.0 (16.6)	10-15 (3-5)	60
3	-	F.E. Prior & Sons Ltd.	1 City of Guelph	10	3.8 (1.5)	30 (9)	50
4*	G01-60	Standard Aggregates, a Division of Standard Industries	Pt. 4-9 Guelph Twp.	Div. B SE of Waterloo Rd.	198.0 (80.1)	20 (6)	35-60
					297.8 (120.5)		
UNLICENCED PITS**							
5	G09-60	Duffy	10	3B		15 (5)	45
6	G09-016	Stann	16	6D		30 (9)	70 (overgrown)
7	G09-003	Heckendorn	15	4D		12 (4)	40 (overgrown)
8	G09-086	Marden Ready Mix	14	3D		15 (5)	70 (depleted)
9	G09-132	Guelph Twp.	15	3D		15 (5)	30 (rehabilitated)
10	G09-054	Ignatius College	7	3D		12 (4)	40
11	G09-077	E. Place	26	1D		15 (5)	30
12	G09-017	Parkinson	10	9		12 (4)	45
13	G09-052	Royce	10	8		12 (4)	25
14	G09-015	Holman	6	6C		10 (3)	45
15	G09-111	Holman	6,7	7C		25 (8)	60
16	G09-102	Cox Const.	7	7C		25 (8)	60
17	G09-032	Mann Const.	8	7C		25 (8)	60
18	G09-117	Revenue	5	4C		5-20 (1.5-6)	35-70 (depleted)
19	G09-118	Unknown	7	3C		10 (3)	65

*Licenced as both a pit and a quarry.

**Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
20	G09-115	Sinclair	8	2C		-	50
21	-	Guelph Sand & Gravel Ltd.	2 21	1E A		15 (5)	25 (depleted)
22	-	D. Martin Excavating	2	2B		10 (3)	20 (rehabilitated)
23	G01-046	G. Westcott	2	4B		12 (4)	20

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1a	325 (132)	135 (55)	13 (5)	177 (72)	18 (6)	8 (7)
1b	100 (40)	6 (2)	0 (0)	94 (38)	12 (4)	3 (3)
2	1450 (590)	280 (113)	153 (62)	1020 (415)	15 (5)	38 (34)
3a	260 (105)	100 (40)	0 (0)	160 (65)	30 (9)	12 (11)
3b	550 (223)	190 (77)	<1 (<1)	360 (146)	15 (5)	14 (13)
4	720 (290)	225 (91)	3 (1)	495 (200)	15 (5)	19 (17)
	3400 (1380)	940 (380)	169 (68)	2300 (930)		94 (85)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, CITY OF GUELPH AND GUELPH TOWNSHIP

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
0-3 (0-1)	Guelph	50* (15)	230 (93)	41 (37)
3-25 (1-8)	Guelph	50* (15)	5900 (2390)	1060 (960)
25-50 (8-15)	Guelph	50* (15)	25,500 (10 300)	4600 (4150)
			31,500 (12 700)	5700 (5200)
0-3 (0-1)	Amabel (Eramosa Member)	50 (15)	230 (93)	41 (37)
3-25 (1-8)	Amabel (Eramosa Member)	50 (15)	1720 (700)	310 (280)
25-50 (8-15)	Amabel (Eramosa Member)	50 (15)	600 (240)	108 (98)
			2550 (1030)	460 (415)
			34,000 (13 800)	6100 (5500)

*Thickness varies from 0 to >60 feet (0 to >18 m) throughout the report area.

TABLE 5. QUARRIES, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
LICENCED QUARRIES						
Q1	-	Guelph Dolime Limited	Pt. 1-5 Guelph Twp.	5G	130.0 (52.6)	42 (13)
			Pt. 1,2 City of Guelph	4G		
Q2	-	Standard Aggregates, a Division of Standard Industries	Pt. 4-9 Guelph Twp.	Div. B.S.E. Waterloo Road	198.0 (80.1)	-
					328.0 (132.7)	
UNLICENCED QUARRIES*						
Q3	G09-010	Guelph Reformatory	City of Guelph			30 (9)

*Abandoned quarries or wayside quarries operating on demand under authority of a permit.

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, CITY OF GUELPH AND GUELPH TOWNSHIP.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
1	0-25 (0-8)	380 (155)	40 (16)	0 (0)	340 (140)	45 (14)	55 (50)
2	3-25 (1-8)	350 (140)	160 (65)	0 (0)	190 (75)	60 (18)	41 (37)
3	3-25 (1-8)	1180 (475)	320 (130)	0 (0)	860 (350)	60 (18)	185 (167)
		1910 (770)	520 (210)	0 (0)	1390 (560)		280 (255)

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Cambrian: The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed

aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic Era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear de-

posits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near- ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine- grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin- bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive- bedded, fine-to medium-grained dolostone.

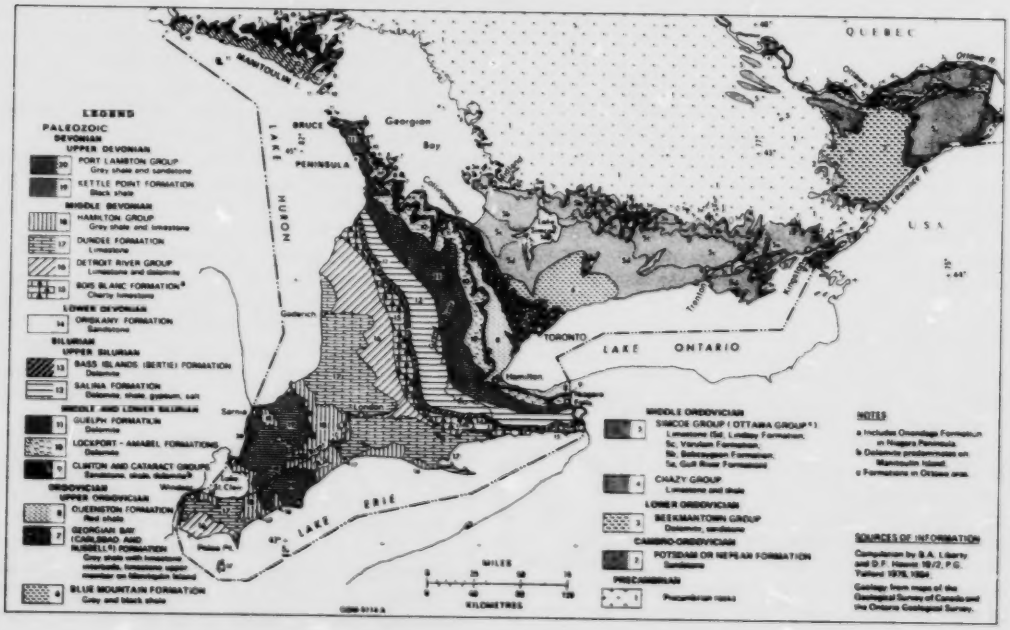


Figure 2. Bedrock Geology of Southern Ontario.

Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium- grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey- brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to microcrystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician) (Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

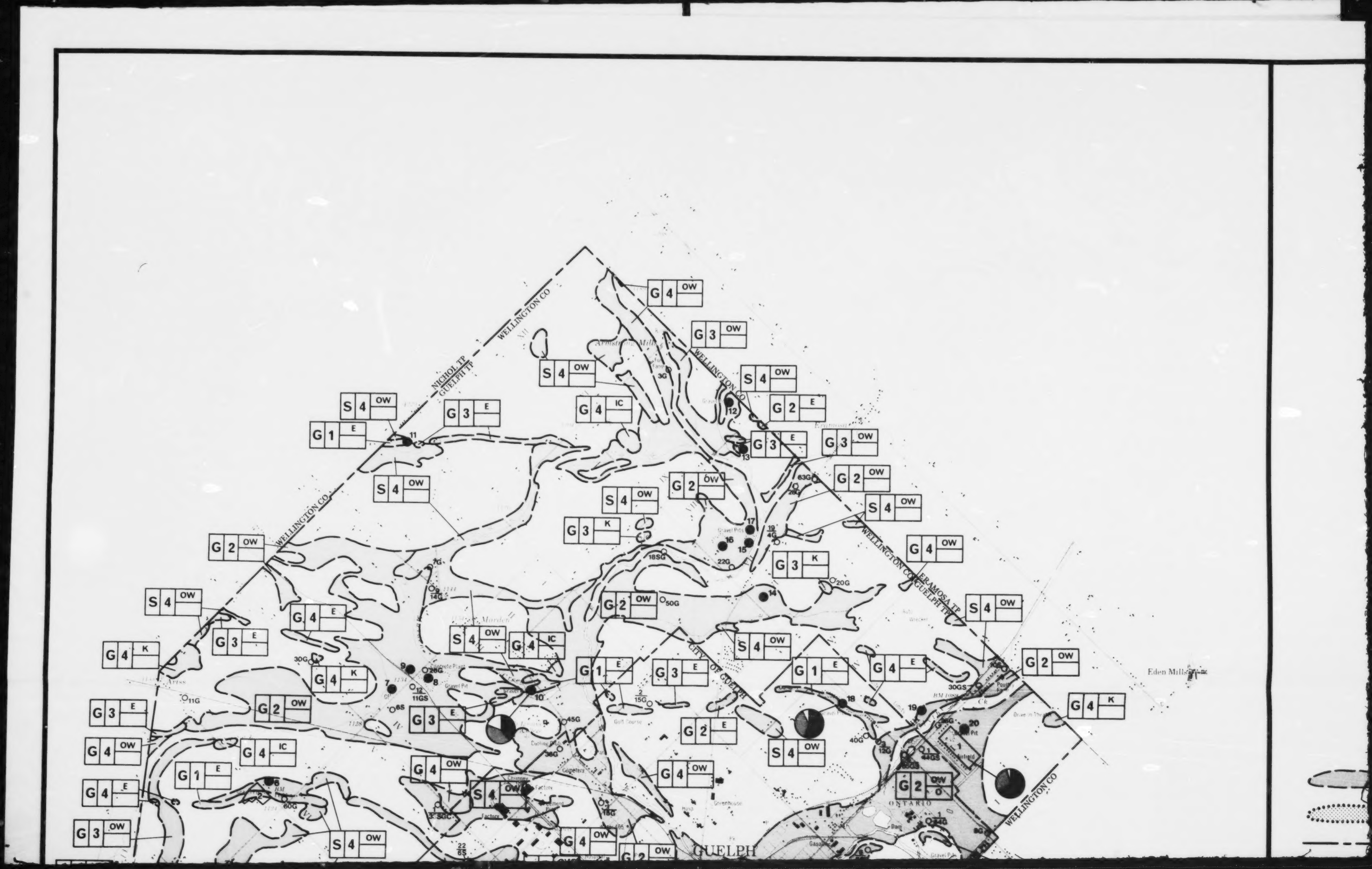
Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

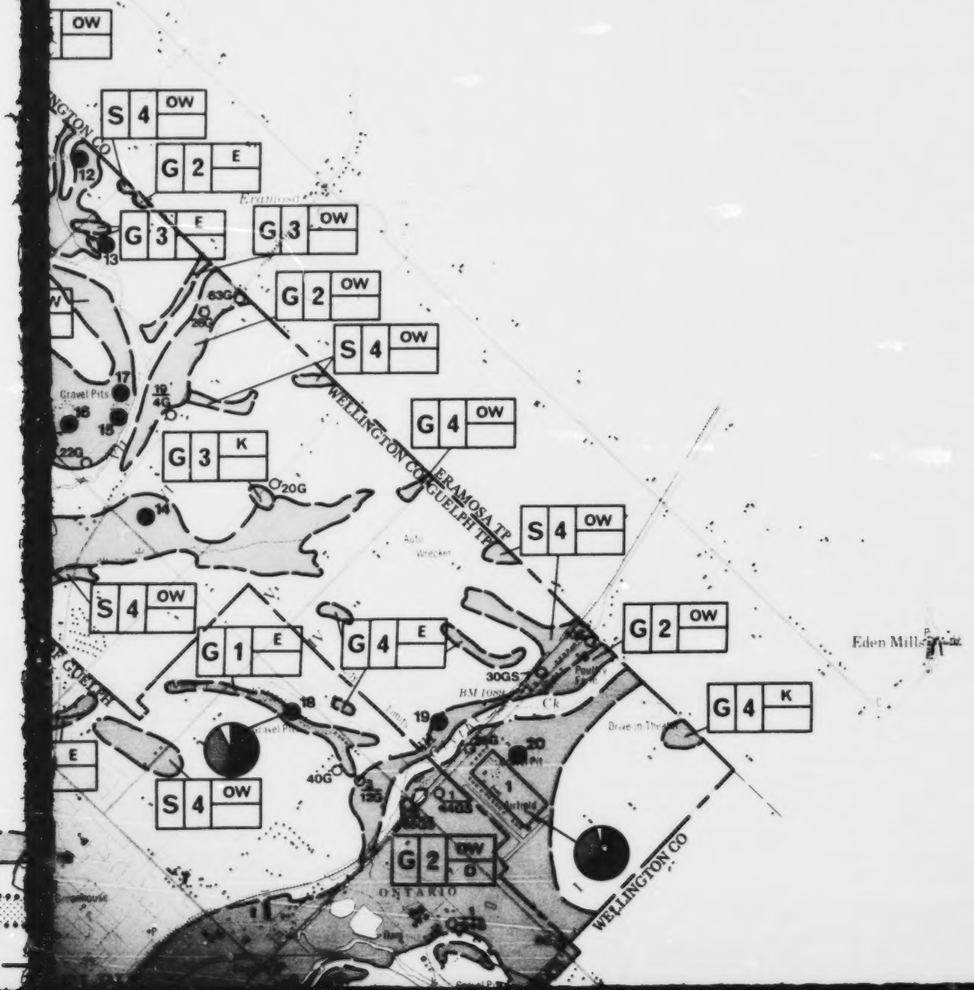
Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.


NICHOL TP
GUELPH TP
WELLINGTON CO
ERAMOSA TP
CITY OF GUELPH
ONTARIO
GUELPH
Eden Mills
G 4 OW
G 3 OW
S 4 OW
G 4 IC
G 3 E
G 2 E
G 1 E
G 2 OW
G 3 K
G 4 E
G 4 K
G 3 E
G 2 OW
G 4 IC
G 1 E
G 4 OW
G 4 E
G 3 OW



Ministry of Northern Affairs and Mines

Ontario

ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

CITY of GUELPH and GUELPH TOWNSHIP

WELLINGTON COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/8, 40 P/9

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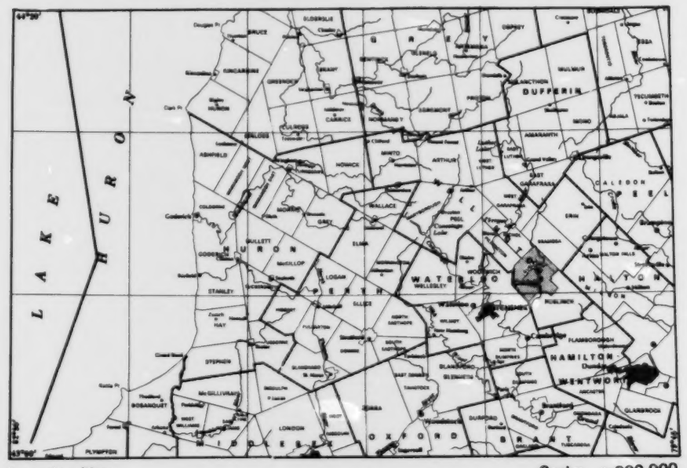


Location Map

Scale: 1:800,000

SYMBOLS

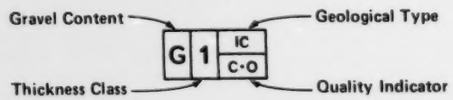
(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

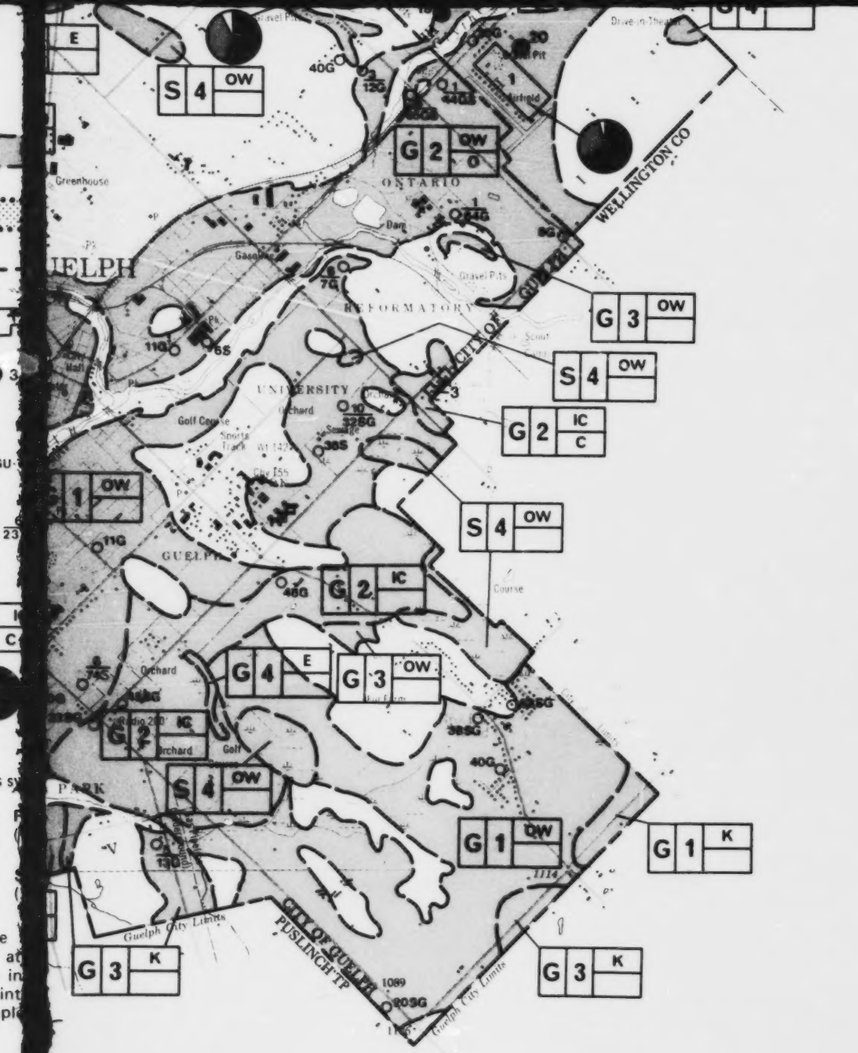
DEPOSIT SYMBOL



Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and

CITY OF GUELPH

GUELPH TP



CITY OF GUELPH
GUELPH TP

SYMBOLS

(Some symbols may not apply to this map.)

Geological and aggregate thickness boundary. Shading indicates deposit area.

Buried geological and aggregate thickness boundary. Shading indicates deposit area.

Municipal boundary.

2 — Licenced property boundary; Property number: see Table 2.

3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
*Abandoned pit or wayside pit operating on demand under authority of a permit.

GU-TH-2 — Selected test hole location; Identification number: see Table 7.

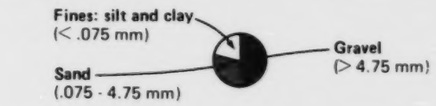
6 / 23 G — Selected drilled water well location; reported thickness of material (in feet); reported type of material (number only - overburden, T - till, G - gravel, S - sand, C - clay, Bk - bedrock).

G 1 IC C·O — Deposit Symbol: see below.

Texture symbol: see below.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)



The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12, 500 (< 28 000)

Geological Type

AL	Older Alluvium	**K**	Kame
E	Esker	**LB**	Lacustrine Beach
EM	End Moraine	**LD**	Lacustrine Delta
IC	Undifferentiated Ice-Contact Stratified Drift	**LP**	Lacustrine Plain
		OW	Outwash
ICT	Ice-Contact Terrace	**WD**	Windblown Forms

(see Appendix C for descriptions of Geological Types)

Quality Indicator

	If blank, no known limitations present.
C	Clay and/or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

SOURCES OF INFORMATION

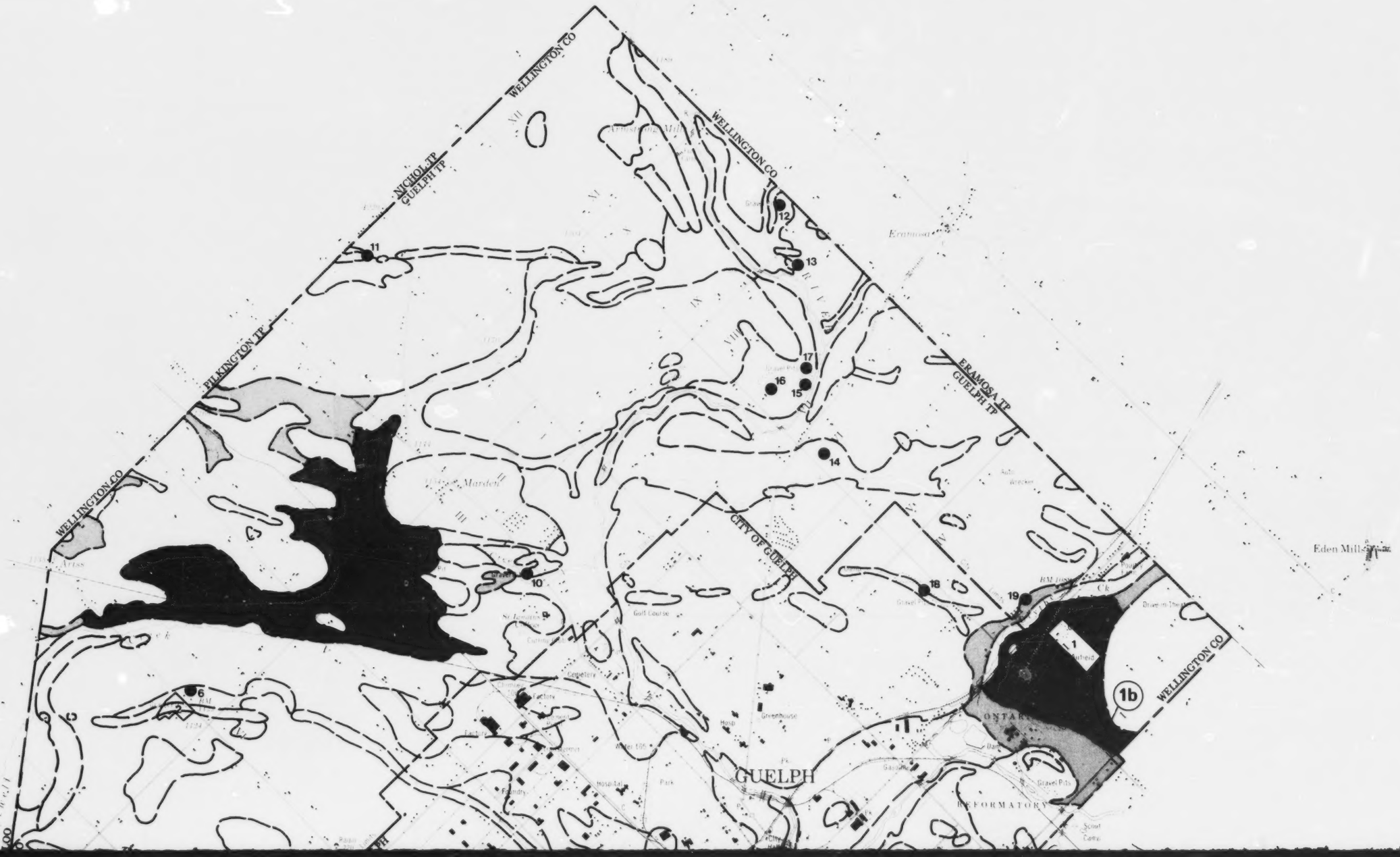
Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Northern Affairs and Mines.
Selected drilled water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P. F. Karrow, 1968, 1983.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 88.

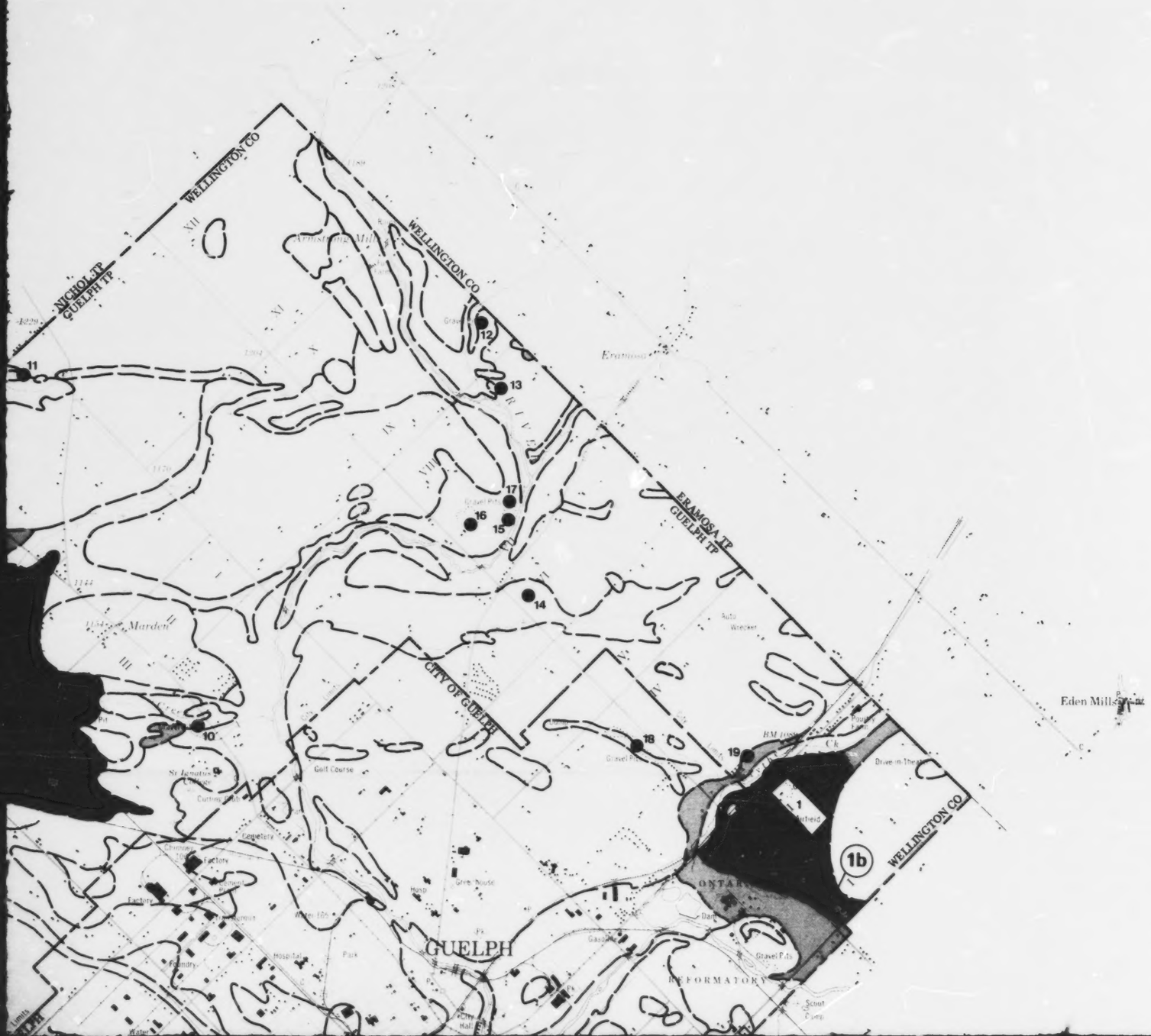
This map is published with the permission of V. G. Milne, Director, Ontario Geological Survey.
Issued 1985.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.



CITY of

Location Map



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ONTARIO GEOLOGICAL SURVEY

AGGREGATE RESOURCES INVENTORY

CITY of GUELPH and GUELPH TOWNSHIP

WELLINGTON COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1:50 000

Mile 1 0 1 Mile

Metres 1000 0 1 Kilometre

NTS Reference: 40 P/8, 40 P/9

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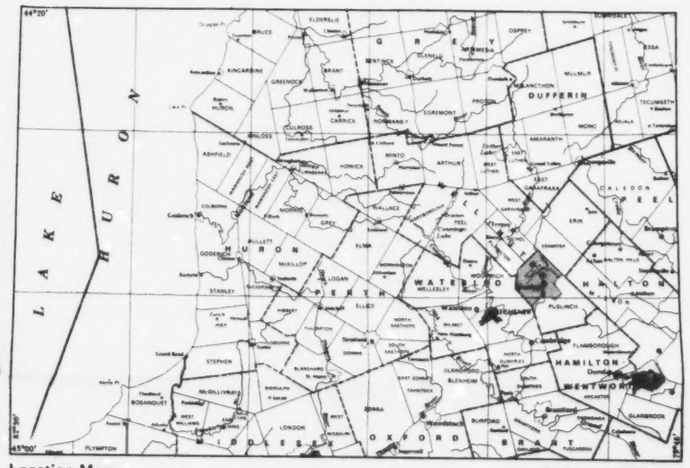


Location Map

Scale: 1:800,000

SYMBOLS

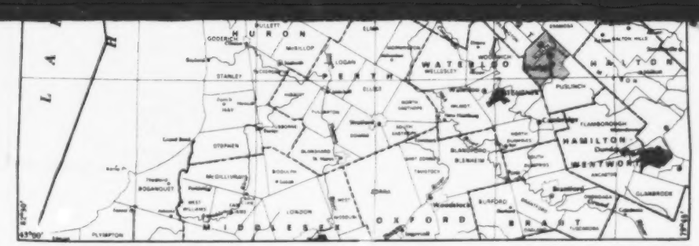
(Some symbols may not apply to this map.)

— — — — Geological and aggregate thickness boundary.

•••••••••••••••••• Buried geological and aggregate thickness boundary.

——— – ——— Municipal boundary.

CITY OF GUELPH
GUELPH TP



Location Map

Scale: 1:800,000

SYMBOLS

(Some symbols may not apply to this map.)

- Geological and aggregate thickness boundary.
- Buried geological and aggregate thickness boundary.
- Municipal boundary.
- Selected sand and gravel resource area; Primary significance; Deposit number: see Table 3.
- Selected sand and gravel resource area; Secondary significance.
- Selected sand and gravel resource area; Tertiary significance.
- 2 — Licenced property boundary; Property number: see Table 2.
- 3 — Unlicenced sand or gravel pit*; Property number: see Table 2.
  *Abandoned pit or wayside pit operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Geology by: P. F. Karrow, 1968, 1983.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.
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NICHOL TP
GUELPH TP
WELLINGTON CO
WELLINGTON CO
GUELPH FORMATION
PILKINGTON TP
GUELPH TP
WELLINGTON CO
FRAMOSA TP
GUELPH TP
GUELPH FORMATION
GUELPH FORMATION
PUSLINCH TP
GUELPH FORMATION
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N

Ministry of Northern Affairs and Mines

Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

CITY of GUELPH and GUELPH TOWNSHIP

WELLINGTON COUNTY

MAP 3
BEDROCK RESOURCES

Scale 1:50 000

Mile 1 0 1 Mile
Metres 1000 0 1 Kilometre

NTS Reference: 40 P/8, 40 P/9

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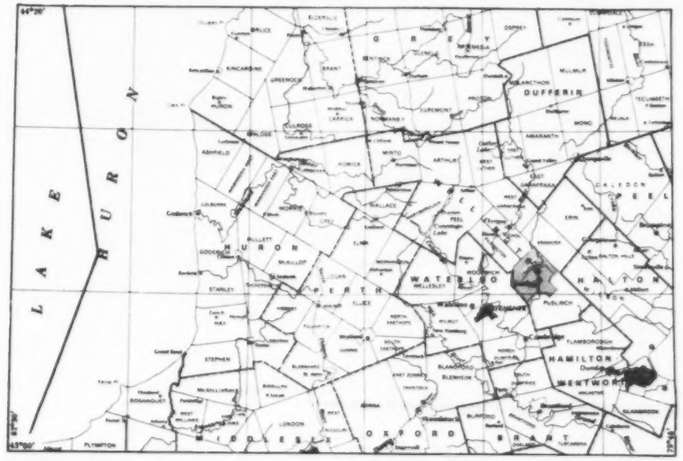

Location Map

Scale: 1:800,000

LEGEND

PALEOZOIC

SILURIAN

MIDDLE SILURIAN

GUELPH FORMATION

SYMBOLS

(Some symbols may not apply to this map.)

Geological formation boundary.

Geological formation member boundary.

Formation thickness boundary (see text).

25 Drift thickness contour: 25 foot (8 m) interval.

GUELPH FORMATION

GUELPH FORMATION

GUELPH FORMATION

GUELPH FORMATION

GUELPH FORMATION

RM OF WATERLOO
WELLINGTON CO

CITY OF GUELPH

GUELPH TP
WOOLWICH TP

WELLINGTON CO

CITY OF GUELPH
PUSLINCH TP

PUSLINCH TP

WELLINGTON CO

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CITY OF GUELPH
GUELPH TP

CITY OF GUELPH
GUELPH TP

Location Map

Scale: 1:800,000

LEGEND

PALEOZOIC

SILURIAN

MIDDLE SILURIAN

GUELPH FORMATION
Dolostone

AMABEL FORMATION
Dolostone

SYMBOLS

(Some symbols may not apply to this map.)

- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 — Drift thickness contour: 25 foot (8 m) interval.
- Municipal boundary.
- (2) Selected bedrock resource area; Deposit number: see Table 6.
- Bedrock exposed or near surface; covered by less than 3 feet (1 m) of overburden: see Table 4.
- Bedrock covered by 3 to 25 feet (1 to 8 m) of overburden: see Table 4.
- Bedrock covered by 25 to 50 feet (8 to 15 m) of overburden: see Table 4.
- x Isolated bedrock outcrop.
- Q2 Licenced quarry boundary; Property number: see Table 5.
- Q3 Unlicenced quarry*; Property number: see Table 5. *Abandoned quarry or wayside quarry operating on demand under authority of a permit.
- O 28 Selected drilled waterwell location; reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by: P. G. Telford, 1976, 1979.

Compilation and Drafting by: Staff of the Cambridge District Office, Ontario Ministry of Natural Resources; Aggregate Assessment Office, Ontario Ministry of Northern Affairs and Mines.

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